

MAS Simulator: A Laboratory Set Up

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Abstract— Detailed procedure for laboratory set up of Miniature Aerial System (MAS) simulator. MAS have three parts viz., Miniature (unmanned) air vehicle (MAV), wireless communication link and ground control station (GCS). For testing, flying MAV every time is more expensive and not viable. To overcome this problem, a laboratory based Miniature Aerial Vehicle Flight Simulator (MAVFS) has been developed by replicating MAV with hardware and software. Hardware and software used in GCS is similar for both real time application and simulation. It provides three main functions of mission planning/tracking, observing and piloting. GCS controls the MAVFS through a Wireless Communication Link (WCL).

Keywords — Miniature Aerial Vehicle, Flight simulator, Ground Control station, hardware & software interface, data communication.

I. INTRODUCTION

Miniature Aerial System (MAS) has found various uses in both commercial and military applications for collecting information about different places where humans cannot venture. In military context, the MAS are used for surveillance; air strikes, exploration and rescue processes, assisting hostage situations and for explosive dangers, and tracing illegitimate. Technology development in the design of MAS opens their exploitation in a variety of civilian application. In civil context, the MAS are used for atmospheric monitoring, traffic monitoring, resource exploration, electricity inspection, forest fire prevention and agriculture where it has broad prospects. Geographical navigation and guidance decide how to move from the current position to destination. When the Miniature Aerial Vehicle (MAV) is out of sight, control of mission is done in ground control station (GCS) by visualizing the video transmitted from the camera in MAV. To do that operator has to be trained well. For training or testing, flying MAV every time is more expensive and not viable. Thus, a laboratory based Miniature Aerial System (MAS) Simulator has been developed and demonstrated at MSDF Lab. Using this simulator, the flight test hours for the real MAV equipment will be reduced; hence its service hours will be increased and cost of aircraft development can be minimized. This simulator can be used to test the subsystems such as flight control, wireless communication and ground control station functions, and aerial vehicle etc.

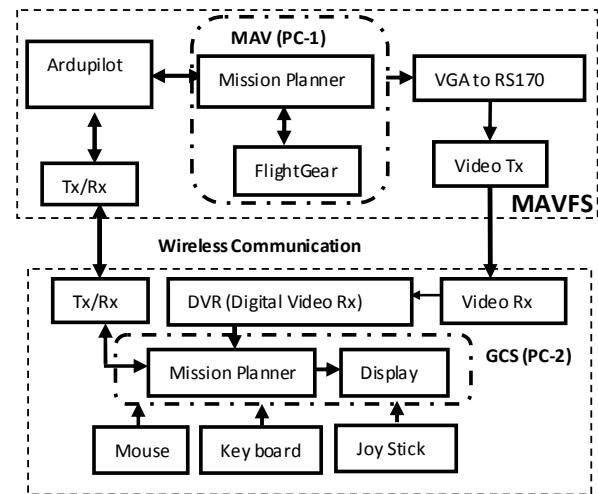


Fig. 1. Block diagram of Miniature Aerial System

II. MINIATURE AERIAL SYSTEM (MAS)

Miniature Aerial System (MAS) has three major components viz.,

- Miniature Aerial Vehicle Flight Simulator (MAVFS)
- Wireless Communication link (WCL)
- Ground Control Station (GCS)

GCS controls the MAVFS through a WCL. Laboratory setup of MAS Simulator is made using FlightGear simulator with hardware as shown in Fig. 1.

A. Miniature Aerial Vehicle Flight Simulator (MAVFS)

Flying an aerial vehicle every time for mission planning research is more expensive, hence MAVFS is proposed. MAV module mainly consists of an ArduPilot Mega chip (APM 2.5) which is used for controlling the MAV [1] and a Gimbaled camera which will be continuously transmitting video data to GCS [2] through the video transmitter card, in order to improve the operator's situational awareness. MAVFS is built using ArduPilot Mega (APM 2.5) board with FlightGear simulator. Fig. 2 shows the information flow diagram of MAVFS and its components. FlightGear is a open source flight simulator [3] which can simulate the MAV flight parameters, telemetry data

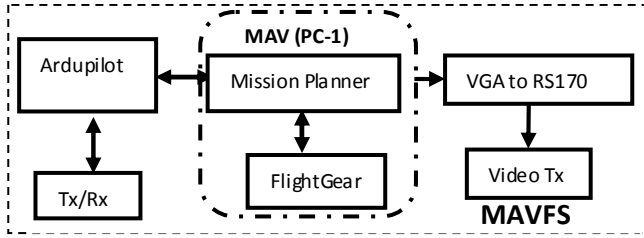


Fig. 2. Block diagram of Miniature Air Vehicle

and video feed of a real MAV with gimbaled camera. But the video obtained in the default FlightGear flight simulator is synthetic. So, in order to have real time experience, photoscenery [4] is generated and integrated with FlightGear. Fig. 3 shows the photoscenery of NAL (National Aerospace Laboratories), Bangalore in FlightGear by which realistic terrain visualization as that of Google Earth is experienced. Resolution of photoscenery depends on the capabilities of the graphics hardware of the system; higher end graphic card can give much better resolution. Here, APM 2.5 is used to control the FlightGear Simulation. In order to interconnect APM 2.5 with FlightGear, Mission Planner (GCS Software) is used. APM 2.5 is connected to the Mission Planner through USB port by which MAVlink connection is established between ArduPilot and Mission Planner. By means of Mission Planner an operator/pilot can interact with the board. Then from Mission Planner, FlightGear is started which establish MAVlink connection between FlightGear and Mission Planner. By using synchronized virtual socketting, Mission Planner is enabled to control the FlightGear. MAV and GCS are connected through wireless communication. As of that, here XBee PRO RF [6, 7] is used as transceiver for wireless communication. Since, XBee PRO RF is with 2.4 GHz for worldwide development and with 900MHz for long range development, it can transmit data at high speed with less delay. Transceiver is connected to APM 2.5 board to transmit navigational data and to receive control command from GCS. Camera view (virtual camera view) which is displayed in monitor as VGA format is converted to RS170 through VGA to RS170 converter and then transmitted to the GCS, through RF video transmitter [8, 9].

B. Ground Control Station(GCS)



Fig. 3. Photoscenery of FlightGear, NAL, Bangalore

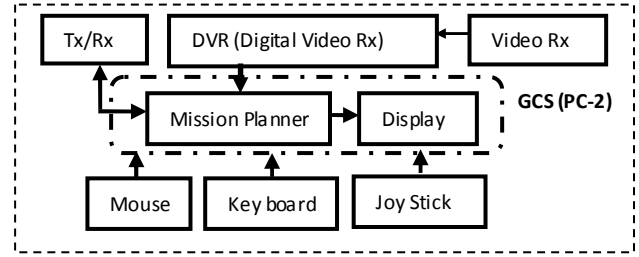


Fig. 4. Block diagram of Ground Control Station

The Ground control station is a contact center for MAV and ground staff. It is also called as the nerve center of activity during MAV missions as it provides necessary information to plan and execute the MAV missions. Ground Control station incorporates facilities to display, communicate (RF communication adopted), and data exploitation. It sends ground commands to MAV, and also receives and displays the MAV flight parameters, such as data related to remote sensing and telemetric data. Ground control architecture is highly process oriented and hence the hardware and software technologies play a major role in the designing of this vital system. Ground control station includes two parts hardware and software component. Hardware component includes XBee PRO RF transceiver, host computer system, auxiliary control system, power system and a user designed remote control system and input devices. The software includes Mission Planner, which helps to establish a wireless data link to obtain and display the MAV flight parameters and perform the ground control operation and send wireless commands to the ArduPilot Mega (APM 2.5) through XBee PRO RF module. Fig. 4 shows the information flow diagram of the ground control station. XBee transceiver is used to transmit control commands and receive the navigational data from MAV. Video receiver is used to receive the video signal from camera in MAV. Video is received in PC by using TV tuner device (DVR) which acts as a frame grabber, that convert analog video to digital frames. DVR is connected to mission planner, by which it receives video. Using Mission Planner operator/pilot can interact with MAV by giving commands as command line or can give inputs through Joystick. To give input through Joystick, it should be connected to Mission Planner through USB port. Logitech Attack 3 is used for control [10, 11].

C. Communication Link

The common thread which binds the MAV and the GCS is the communication link. Communication link is the medium through which GCS controls the MAV missions. Data transfer



Fig. 5. VGA to RS170 converter

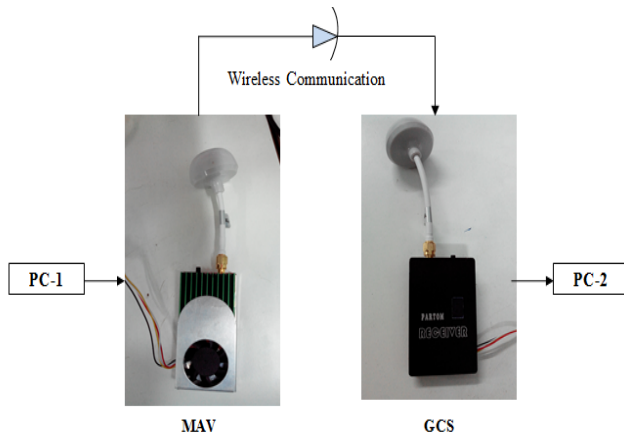


Fig. 6. Wireless AV Transmitter & Receiver FPV-5812

from air to ground and vice versa is also done through this link, hence transmission and reception plays an important role in MAS. It is also known as “the heart of GCS” as it is the pathway for the control command, telemetry and data transfer.

GCS consist of Mission Planning and Control Station, which acts as a base for flying the MAV and issuing commands in case of a data terminal and remote video terminal. Data is generally transmitted from MAV to GCS and vice versa through XBee PRO RF Transceivers which operate at a frequency of 2.4 GHz. XBee PRO RF Transceivers has to be configured with same setting mainly baud rate has to be 57600 for transmission of data and receiving of data and also with appropriate identity name properly to get proper outputs and its destination low byte is set as FFFF for broadcasting of data [12, 13]. A camera is mounted on the MAV which is used to capture the video and transmit to GCS. For transmitting video, video transmitter operates at a frequency of 5.8 GHz is used. In MAS simulator, communication link set up is as that of real MAS. By means of which even future research in time delay reduction, noise reduction and image enhancement techniques can be done at lower cost. In addition to communication link, VGA to RS170 converter [14] is used for transmitting video from FlightGear flight simulator for

realistic experience. Fig. 5 shows the VGA to RS170 converter used for converting VGA to RS170. Then, video from this converter is transmitted to GCS using video transmitter. Fig. 6 shows the video transceiver used for video transmission.

III. SET UP OF MAS

MAS simulator is set up by configuring the MAVFS and GCS with the communication links. Before that XBee should be configured with XCTU software with baud rate of 57600 and with board cast mode of transition. Then, make a check whether both XBee are able to communicate with each other. Once XBee is configured, both MAVFS and GCS are configured separately as follows:

A. Steps to set up PC-1(MAVFS)

PC-1 acts as the MAVFS. PC-1 has following specification

- Processor: Intel i7 CPU 870 @ 2.93GHz
- RAM: 4 GB
- System type: 64 - bit Windows 7 OS
- Graphics card : NVIDIA GeForce 8400GS

For making PC-1 as MAVFS it should have following software and hardware. Fig. 7 shows the Laboratory set up of MAVFS.

1) Software Required in PC-1(MAVFS)

- a) Mission Planner-1.3.10 [15] (needs .NET framework version 4.0)
- b) Flight Gear (compiled with photoscenery support)
- c) APM 2.5 board drivers [16]

2) Hardware Required in PC-1(MAVFS)

- a) APM 2.5 (Ardu Pilot Mega board)
- b) XBee (able to connect with APM 2.5)
- c) VGA to RS170 Video Converter
- d) Video transmitter

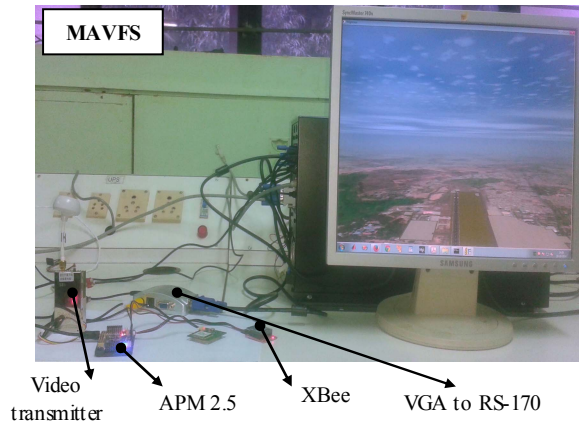


Fig. 7. Hardware Components of MAVFS

- Install all the software and drivers required.
- Load the HIL mode firmware in to APM 2.5 using Mission Planner, so that it disables all the sensors in APM board and enables it to get signal from FlightGear [17-20].
- APM 2.5 should be connected to Mission Planner at baud rate of 115200.
- XBee transceiver should be connected to the APM board.
- VGA to RS170 video converter should be connected between PC-1 and video transmitter.

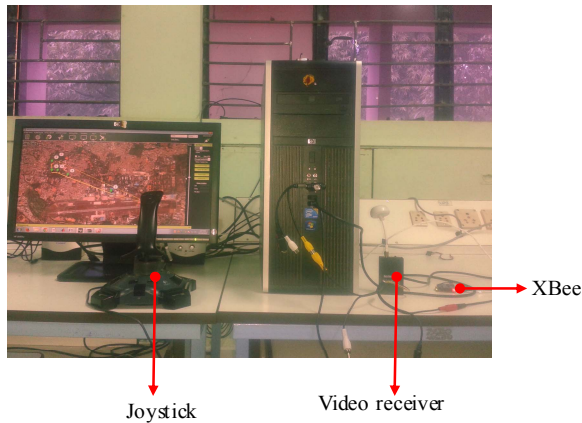


Fig. 8. Laboratory Set Up Of GCS

- Start the FlightGear in simulation tab and then press start simlink which will create MAVlink between them.

B. Steps to set up PC-2 (GCS)

PC-2 is act as GCS. PC-2 has following specification

- Model: HP Compaq 8100 Elite CMT PC
- Processor: Intel i5 CPU 650 @ 3.20GHz
- RAM: 2 GB

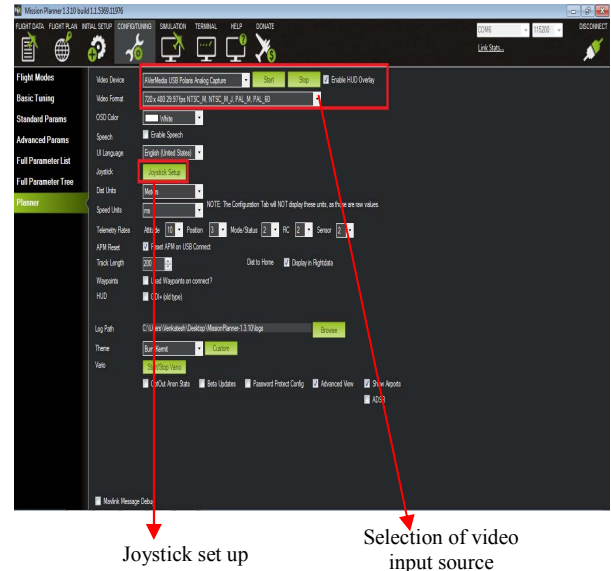


Fig. 9. Selection of video source and control input in Mission Planner

- System type:32- bit Windows 7 OS

For making PC-2 as GCS it should have following software and hardware. Fig. 8 shows the laboratory set up of GCS.

1) Software Required in PC-2 (GCS)

a) Mission Planner-1.3.10



Fig. 10. Flight parameter in GCS with transmitted video in OSD screen

- b) XBee driver [22]
- c) Aver TV Volar Go tuner driver [23]

2) Hardware Required in PC-2 (GCS)

- a) XBee (able to connect with APM 2.5)
- b) Video receiver
- c) Joystick
- d) DVR TV tuner (Aver TV Volar Go)
- Install all the software and drivers required.
- Connect APM with Mission Planner through the XBee.
- Connect the joystick and enable it in Mission Planner. DVR TV tuner is connected to Video receiver by which video is received in PC-2. Fig. 9 shows the enabling of joystick by its name and video source.
- Enable the TV tuner card in Mission Planner and then get the video from it in Mission Planner OSD screen.
- Give waypoint, tune the parameters and start the mission [24, 25].

IV. RESULT

Once simulation is started, flight movement is indicated in the screen of GCS. Aircraft will start moving in the path given as waypoint. When we want to control it manually, we can give input through joystick connected to GCS. This input is given higher priority than the control input of Mission Planner. The flight trajectory can be controlled using this joystick. It also changes its path from given waypoint according to joystick input. Since input is given in GCS and FlightGear is in MAVFS, so there will be delay in output. Once joystick input is stopped, again Mission Planner takes control of mission and it tries to regain its waypoint path then starts following the path automatically. Fig. 10 show flight parameter with response of flight in GCS to input in MAVFS.

A. Advantages

- Set up of MAV simulator gives real time experience with wirelessly transmitted video.
- Pilot can be trained to control the MAV with camera view.
- Since MAVFS replicate the real MAV, even time delay in control input can be experienced and pilot are trained accordingly, which improves efficiency of pilot.
- Research in time delay reduction, noise reduction and image enhancement techniques can be done through this simulation.
- Simulator can be used to test new hardware and software in the subsystems.

V. CONCLUSION

Miniature Aerial System (MAS) has been designed and developed for laboratory use. Details on installation of different software and hardware are provided. This laboratory

setup can be used extensively for developing image processing algorithms, tracking algorithms and it can be used for MAV pilot/operator training. Using this simulator, development cost of aircraft can be minimized. In this harmless situation a trainee can do mistakes and learn or study from them, and they can also redo standard, nonstandard trials and techniques which is not applicable and dangerous when performed in real MAS.

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REFERENCES

- [1] The APM 2.5 Board Overview- http://copter.ardupilot.com/wiki/apm2.5_board_overview accessed on 4th September -2014J.
- [2] Using a Ground Station- <http://copter.ardupilot.com/wiki/common-using-a-ground-station/> accessed on 4th September -2014.
- [3] Configuration of flight gear <https://code.google.com/p/ardupilotmega/downloads/detail?name=system.fgfsrc> accessed on 4th September -2014
- [4] A. Srikanth, B. Indhu, L. Krishnamurthy and VPS Naidu, "Realistic Scene Generation and Visualization in FlightGear: A Tutorial", IJAREEIE, Vol. 3, Special Issue 5, December 2014.
- [5] Configuring XBee -<http://www.instructables.com/id/Changing-Xbee-Baud-Rates> accessed on 4th September -2014
- [6] Product manual for XBee/XBee-PRORF Modules, Digi's International Inc, IEEE® 802.15.4 RF Modules by Digi's International, 2012
- [7] XBee wireless communication set up - <http://eeewiki.net/display/Wireless/XBee+Wireless+Communication+Setup> accessed on 4th September -2014.
- [8] Product description of FPV 5.88g 1200mw 9CH Wireless AV Transmitter &Receiver (FPV-5812 5.8g) <http://transmitters88.en.made-in-china.com/product/SosnYCbyvR-M/> accessed on 9th September -2014.
- [9] Product description of FPV 5.88g 1200mw 9CH Wireless AV Transmitter &Receiver http://www.alibaba.com/product-detail/5-8G-1200mW-5-8g-fpv_1726 accessed on 9th September -2014
- [10] Attack™ 3 Joystick <http://www.logitech.com/en-in/support/attack-3-joystick?osid=14&bit=64> accessed on 4th September -2014
- [11] Using a computer joystick/ gamepad instead of RC for manual control <https://code.google.com/p/Ardupilot-mega/wiki/Joystick>, accessed on 4th September -2014.
- [12] XBee Testing & Configuration - <http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&ved=0CGEQFjAM&url=http%3A%2F%2Fforums.parallax.com%2Fattachment.php%3Fattachmentid%3D72478%26d%3D&ei=SfYGVOPAB8ucugSGoILgCQ&usq=AFOjCNHPcyXWYU9jXaVqpGNz7JH4nXw8zg&bvm=bv.74115972,d.c2E&cad=rja> accessed on 4th September -2014.
- [13] Connecting XBee to mission planner-<http://copter.ardupilot.com/wiki/xbee-radios/> accessed on 4th September -2014.
- [14] VGA to RS170 converter - http://shopping.rediff.com/product/vga-to-pal-laptop-pc-to-tv-video-scan-converter/11513161?sc_cid=www.google.co.in/search accessed on 4th September -2014

- [15] Mission Planner-1.3.10 downloaded from -<http://ardupilot.com/wp-content/plugins/download-monitor/download.php?id=82> accessed on 4th September -2014.
- [16] APM board drivers downloaded from - <http://ardupilot.com/downloads/?did=19> accessed on 4th September -2014.
- [17] Hardware in the loop simulation with Ardupilot, Flightgear and Linux-<http://diydrones.com/profiles/blogs/hardware-in-the-loop-simulation-with-ardupilot-flightgear-and-1> accessed on 4th September -2014.
- [18] X-Plane Hardware in the Loop Simulation-<http://planner.ardupilot.com/wiki/common-simulation/> accessed on 4th September -2014.
- [19] How to set up a full Hardware-in-the-loop simulation with Flightgear-<https://code.google.com/p/ardupilot-mega/wiki/FlightGear> accessed on 4th September -2014.
- [20] HIL Quad Simulator-<http://copter.ardupilot.com/wiki/hil-quad/> accessed on 4th September -2014.
- [21] Mandatory APM 2.5 Hardware Configuration-<http://copter.ardupilot.com/wiki/initial-setup/configuring-hardware/> accessed on 4th September -2014.
- [22] XBee driver – downloaded from - <http://www.digi.com/support/productdetail?pid=3250&type=drivers> accessed on 4th September -2014.
- [23] Aver TV Volar Go tuner driver – downloaded from - <http://avertv.avermedia.com/Product/ProductDetail.aspx?Id=495&tab=APDriver> accessed on 4th September -2014.
- [24] Mission Planner-<http://planner.ardupilot.com/> accessed on 4th September -2014.
- [25] Planning a Mission with Waypoints and Events <http://planner.ardupilot.com/wiki/common-planning-a-mission-with-waypoints-and-events/> accessed on 4th September -2014.